Field volatility of Dicamba BAPMA

Report:	MRID 51049002. Toth, B.N. Off-target Movement Assessment of a Spray Solution Containing BAS 183 22 H and a Tank Mix Partner – Missouri. Unpublished study performed by Stone Environmental, Inc., Montpelier, Vermont; Eurofins EAG Agroscience, LLC, Columbia, Missouri; and AGVISE Laboratories, Northwood, North Dakota; sponsored and submitted by BASF Corporation, Research Triangle Park, North Carolina. Stone Study ID: 19-059-B. Eurofins Study ID: 89024. BASF Study ID: 884978. Agvise Study ID: 19-1582, 19-1583 and 19-135. Study initiation August 7, 2019 and completion October 12, 2019 (p. 6). Study and Report completion January 28, 2020.
Document No.:	MRID 51049002
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with US EPA FIFRA GLP standards (40 CFR Part 160) with the exception of test site observations, slope estimates, pesticide and crop history, soil taxonomy, application summary and spray rate data, and study weather data (p. 3). Signed and dated Data Confidentiality, GLP Compliance, Quality Assurance, and Authenticity Certification statements were provided (pp. 2-4, and 7).
Classification:	This study is **acceptable**. Monitoring started after the conclusion of application. An independent laboratory method validation was not conducted. The addition of an approved buffering agent was included in the tank mix but was not included in the protocol reviewed by EPA. This adds uncertainty to the volatile flux rates, as the buffering agent may have reduced volatility of dicamba.
PC Code:	100094

Final EPA Reviewer:	Chuck Peck Senior Fate Scientist	Signature: Date: 2020.10.24 20:08:38 -04'00'
Final EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist	Signature: Date: 2020.10.25 12:25:34 -04'00'
CDM/CSS-Dynamac JV Reviewers:	Dan Hunt, M.S. Environmental Scientist	Signature: Dan Hunt Date: 4/15/20
	Richard Lester Environmental Scientist	Signature: Richard R Lester Date: 4/15/20

This Data Evaluation Record may have been altered by the Environmental Fate and Effects Division subsequent to signing by CDM/CSS-Dynamac JV personnel. The CDM/CSS-Dynamac Joint Venture role does not include establishing Agency policies.

Executive Summary

Field volatilization of dicamba formulation BAS 183 22 H (dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt), when tank mixed with Roundup PowerMax®, Intact™ (polyethylene glycol, choline chloride, and guar gum), and an approved buffering agent, was examined from a single dicamba-tolerant soybean-cropped test plot surrounded by non-dicamba tolerant soybean in New Madrid County, Missouri. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. The products were applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-target plants. A control plot was established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures, surface soil temperatures, and relative humidity the day of application (9/12/19) ranged from 24.1-46.3°C (75.4-115°F), 20.1-36.8°C (68.2-98.2°F), and 46-94%, respectively. Air temperatures, surface soil temperatures, and relative humidity ranged from 18.0-37.6°C (64.4-99.7°F), 22.2-47.6°C (72.0-118°F), and 30-95%, respectively, 1 to 7 days after application.

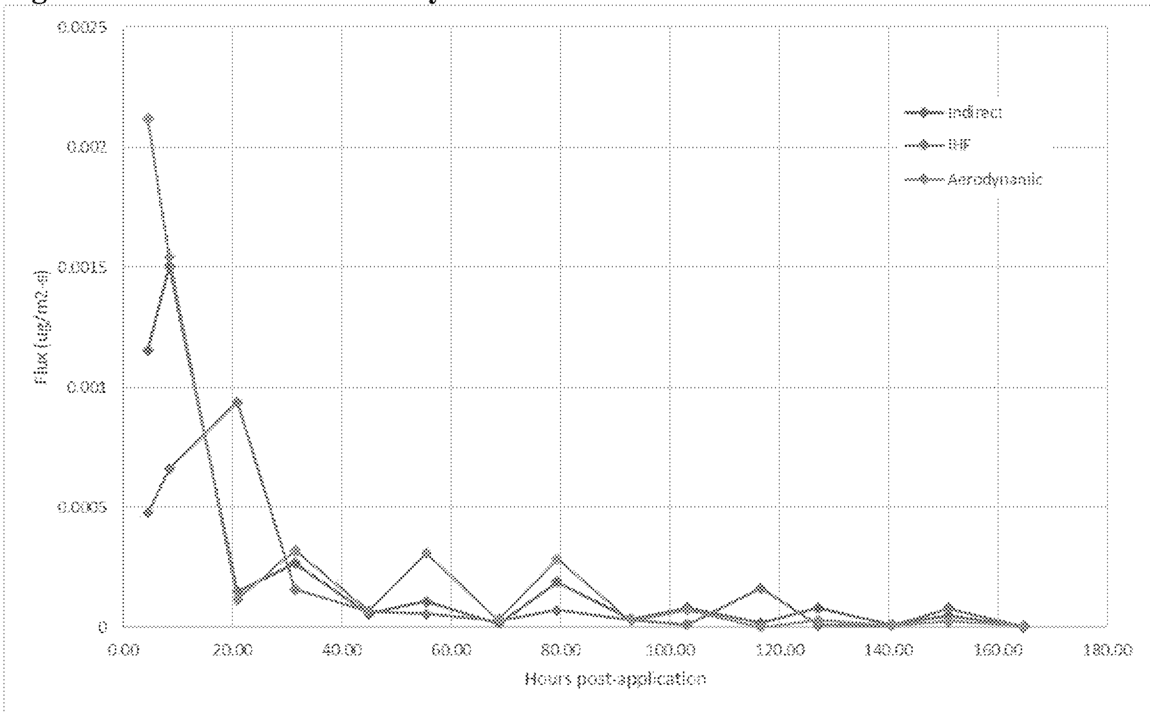
Under field conditions at the test plot, study authors estimated, based on calculations using the Indirect method, a peak volatile flux rate of 0.002981 $\mu g/m^2 \cdot s$, accounting for 0.076% of the applied dicamba, observed 4.5 to 8.5 hours post-application. By the end of the study, study authors estimated that a total of 0.168% of dicamba had volatilized and was lost from the field. The reviewer estimated a peak volatile flux rate of 0.001503 $\mu g/m^2 \cdot s$, accounting for 0.072% of the applied dicamba observed 4.5 to 8.5 hours post-application, with a total of 0.15% dicamba being lost from the field by the end of the study. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Under field conditions at the test plot, study authors estimated, based on calculations using the Integrated Horizontal Flux method, a peak volatile flux rate of 0.001277 $\mu g/m^2 \cdot s$, accounting for 0.031% of the applied dicamba, observed 4.5 to 8.3 hours post-application. By the end of the study, a total of 0.171% of dicamba volatilized and was lost from the field. The reviewer estimated a peak volatile flux rate of 0.000939 $\mu g/m^2 \cdot s$, accounting for 0.075% of the applied dicamba observed 8.5 to 20 hours post-application, with a total of 0.155% dicamba being lost from the field by the end of the study. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Under field conditions at the test plot, study authors and the reviewer estimated, based on calculations using the Aerodynamic method, a peak volatile flux rate of 0.001913 $\mu g/m^2 \cdot s$, accounting for 0.049% of the applied dicamba, observed 0.5 to 4.5 hours post-application. By the end of the study, study authors estimated a total of 0.152% of dicamba volatilized and was lost from the field. The reviewer estimated a peak volatile flux rate of 0.002117 $\mu g/m^2 \cdot s$, accounting for 0.054% of the applied dicamba, observed 0.5 to 4.5 hours post-application total loss was 0.184%. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Spray drift measurements indicated that dicamba residues were detected at very low levels (maximum fraction of 0.000008 of the applied) in upwind samples at one hour after application and were detected at a maximum fraction of the amount applied of 0.003553 in downwind samples and 0.004806 in left wind samples. Deposition of dicamba above the no observed adverse effects concentration (NOAEC) was detected in all transects of the downwind and left wind directions in the one-hour sampling period. Study authors estimated distances from the edge of the field to reach NOAEC for soybean ranged from 6.9 to 15.0 m in the downwind direction and 5.5 to 18.4 m in the left wind direction. Reviewer-estimated distances were 9.98 m (7.07 to 15.64 m for the three transects) and 10.24 m (10.23 to 10.25 m for the two transects) in the downwind and left wind directions, respectively.

Figure 1 Volatile flux – Soybean Plot



Plant effects (51049002, EPA Guideline 850.4150; Supporting files in Appendix 2)

The effect of **BAS 183 22 H (a.i. Dicamba BAPMA salt) + MON 79789 (a.i. Glyphosate potassium salt) + Adjuvant Intact™** on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.50 lb ae/A and Glyphosate were 1.125 lb ae/A. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application and post-application tank solutions; nominal and measured application rates are provided in Table 4. On days 14 and 28 after treatment, the surviving plants along several transects projecting from the treated area were measured for height and visual signs of injury (VSI).

Significant VSI was observed in all control plots on 14DAT (15-20% VSI) and 28DAT (10-15% VSI). The study authors attribute this to an unknown source of dicamba prior to treatment.

Environmental samples were reported by the authors to have dicamba detections prior to application. On 14DAT, a "baseline" VSI across the entire study area was reported as 15%VSI. The study area is located in a center pivot field with an approximate 427 meter (1400 ft) radius. Since the observed VSI were described as being across the entire sensitive crop, it is assumed that this represents evidence of off-field movement that exceeds 427 meters. The relationship of this effect to the application method, applied dicamba product, and potential exposure pathways that resulted in such an exposure event cannot be determined based on the information provided by the study authors or registrants. These effects to controls used in this study severely limit the utility for establishing distances to effect.

Furthermore, this study was conducted in September, far later than the anticipated June/July timeframe. The impacts of the late season on plant growth and how that relates to the magnitude of potential dicamba effects during the summer climate and light cycle is unknown.

Spray Drift + Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions.

When compared to the negative control plot, there were significant inhibitions in seedling height in downwind (DW), left wind (LW), eastern and western transects. DW and LW transects showed the expected distance-dependent response of lower plant heights near the application area than further away. The eastern and western transects did not show this pattern, but had plant heights that were less than the 5% threshold based on control performance. It is important to note that while the controls were used for comparison, they were exposed to an unknown amount and timing of dicamba, showed significant VSI and their height may have been impacted by this exposure. Distances to effect (Table 1a) were primarily determined by visual approximation using plotted distributions of plant height and VSI (see figures below).

At the 14DAT evaluation, visual dicamba symptomology (15% rating) was observed throughout the entire field, including upwind controls, which later were potentially attributed by the author to drift from offsite southern fields (PUF samples from pre-application indicated presence of dicamba). No report of an investigation was provided by the authors. At 28DAT, spray drift transects showing an increase in symptomology (30-50%) included the downwind (DW), left wind (LW), right wind (RW), east wind (ED) and north wind (ND) transects. Distance-dependent symptomology was observed along the DW, LW, RW and ED transects.

Furthest distance to 5% Reduction in Plant Height >120 meters (>394 feet)
Furthest distance to 10% VSI > 120 meters (>394 feet)

Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, and 20 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions and isolated using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. Height effects and VSI were recorded up to 28 days after spray application of the tank mix.

When compared to the negative control plot, the reviewer found no distance dependent patterns for plant height. Significant inhibitions in plant height as compared to the controls were observed for several plots along the DW, LW and UW volatility transects. It is important to note that while the controls were used for comparison, they were exposed to an unknown amount and timing of dicamba, showed significant VSI and their height may have been impacted by this exposure. Distances to effect (Table 1) were determined by visual approximation using plotted distributions of plant height and VSI (see figures below).

At the 14DAT evaluation, visual dicamba symptomology (15% rating) was observed throughout the entire field, including upwind controls, which later were potentially attributed by the author to drift from offsite southern fields (PUF samples from pre-application indicated presence of dicamba). No report of an investigation was provided by the authors. At day 28, volatility study all transects showed visual effects, maximum observed were up to 35%.

Furthest distance to 5% Reduction in Plant Height > 20 meters (>66 feet)
Furthest distance to 20% VSI > 20 meters (>66 feet)

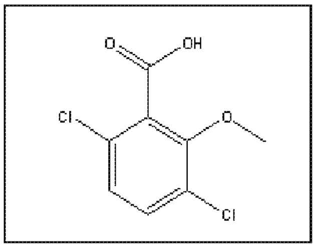
Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

Exposure Pathway	Spray Drift + Volatility		Volatility (Covered Plots)	
Transect [a]	Distance to 5% Height (meters)	Distance to 20% VSI (meters)	Distance to 5% Height (meters)	Distance to 20% VSI (meters)
DWA	>120 [d]	34 [c]	20 [d]	>3 [d]
DWB	34 [c]	>120 [d]	20 [d]	3 [d]
DWC	18 [d]	>120 [d]	20 [d]	>20 [d]
LWA	>60 [d]	>60 [d]	<20 [d]	19 [b]
LWB	>60 [d]	>60 [d]	>20 [d]	14 [b]
UWA	<50 [d]	<5 [d]	>3 [d]	>3 [d]
UWB	<50 [d]	<20 [d]	>3 [d]	>3 [d]
RWA	>3 [d]	>120 [d]	>3 [d]	>20 [d]
RWB	>3 [d]	>120 [d]	>3 [d]	>20 [d]
N	>3 [d]	>60 [d]	NA	NA
S	>3 [d]	17e	NA	NA
E	>60 [d]	44 [c]	NA	NA
W	>60 [d]	40 [d]	NA	NA

[a] distance estimated visually
[b] distance estimated with logistic regression
NA = Not applicable

I. Materials and Methods

A. Materials



1. Test Material

Product Name: BAS 183 22 H (dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt; Appendix B, pp. 100-101)
Formulation Type: SL (soluble concentrate)
CAS #: 105-83-9
Lot Number: 7195N01DD
Storage stability: The expiration date of the test substance was July 18, 2020.

Product Name: Roundup PowerMax® (Glyphosate, (N-(phosphonomethyl) glycine potassium salt; Appendix B, p. 102)
Formulation type: Not reported
CAS Number: Not reported
Lot Number: 11495283
Storage stability: The expiration date of the test substance was May 31, 2021.

Product Name: Intact (polyethylene glycol, choline chloride, guar gum)
Formulation type: Not reported
Lot Number: 0831B037000 (Batch# 374-25)
Storage stability: The expiration date of the test substance was September 11, 2022.

Product Name: Approved buffering agent (ABA)
Formulation type: Not reported
Lot Number: LH-171009-0001
Storage stability: The expiration date of the test substance was July 22, 2022.

2. Storage Conditions

The test substance was received on August 2 and 15, 2019 and stored at MOARK Agricultural Research, LLC, Fisk, Missouri (Appendix B, p. 101). Roundup PowerMax® was received on May 10, 2019. Intact^{TM} was received on May 10 and May 16, 2019. The ABA was received on August 2 and August 15, 2019 (in two separate shipments). The test substance was sprayed on the test plot on September 12, 2019 (Appendix B, p. 105). The study protocol indicates the test substance would be stored under label conditions in a monitored pesticide storage area adequate to preserve stability (Appendix A, p. 37).

B. Study Design

1. Site Description

The test site was located in New Madrid County, Missouri, *ca.* 4.5 miles west of East Prairie, Missouri (Appendix B, p. 103). A single soybean-cropped field, measuring *ca.* 900 ft x 900 ft

(274 m × 274 m, 18.6 A) was treated with a mixture of BAS 183 22 H (containing dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt), Roundup PowerMax® (containing glyphosate potassium salt), Intact™ (polyethylene glycol, choline chloride, and guar gum), and an approved buffering agent (Appendix B, pp. 100-102). The crop on the plot was a dicamba-tolerant soybean crop (Variety: Beck's 4669X2, Lot: A193266M) with a minimum 110-ft buffer surrounding the plot planted in non-tolerant soybeans (Variety: Beck's 4628FP, Lot: R193141M). Soil characterization indicated the USDA textural class was sandy loam/loamy sand (Appendix B, Tables 2-3, pp. 121-122). Prior to the study, the most recent application of dicamba occurred during the 2018 growing season (Appendix B, p. 105), although it is unclear which product applied in 2018 contained dicamba (Appendix C, p. 191). Crop history for the three years preceding the study indicated the field had been planted in corn, soybeans, and cotton (Appendix B, pp. 189-191). Terrain was flat with a slope between 0 and 1%, with the exception of an elevated drive lane through the north corner of the plot leading to the center pivot irrigation system. The center pivot irrigation system was located near the north corner of the plot, extending towards the northwest. The test plot was surrounded by agricultural land (Appendix B, Figure 1, p. 143). The test plot and surrounding buffer zone were planted with soybean on August 1, 2019 and replanted on August 14, 2019 as a result of low emergence due to heavy rain on August 3rd and 6th (Appendix B, p. 103). The soybean seeds were planted at a density of 140,000 seeds/A on 30-inch row spacing for both plantings.

2. Application Details

Application rate(s):	The target application rate was 0.5 lb a.e./A or 15 GPA (Appendix A, p. 37; Appendix B, p. 105). Four application monitoring samples consisting of four filter paper samples each were positioned in the spray area in locations to capture various portions of the spray boom (Appendix B, p. 109). The spray rate was automatically maintained by a variable rate controller (Appendix B, p. 115). Based on Climate FieldView™ software, the actual application rate was 103% of the target application rate or 15.4 GPA (Appendix B, Table 1, p. 120).
Irrigation and Water Seal(s):	No irrigation or water seals were reported in the study. No precipitation was reported during the seven-day field volatility study (Appendix B, Table 13, p. 137).
Tarp Applications:	Tarps were not used on the test plot. Tarps were used on nine plant effects transects before application, during application, and for at least 30 minutes following application to prevent exposure to spray drift to assess secondary movement only (volatility; Appendix A, p. 43). Tarped transects were 100 feet in length.
Application Equipment:	A John Deere R4030 ground sprayer equipped with a 90-ft boom was used for the spray application (Appendix B, p. 104). 73 Turbo TeeJet® Induction nozzles (TTI 11004) were installed with 15-inch

spacing and the boom height was set at 20 inches above the crop canopy. The crop height at the time of application was approximately 20 cm. The sprayer had one spray tank with a volume of 800 gallons.

Equipment Calibration Procedures: Nozzle uniformity was tested by spraying water at a pressure of 63 psi through the boom and measuring nozzle output using SpotOn® Model SC-1 sprayer calibrator devices (Appendix B, p. 104). Each nozzle was tested three times to determine variability. Calibration of the sprayer and nozzles established the total boom output per minute of spray to be 37.2 GPM. The forward speed of the sprayer tractor was calibrated by timing the duration required, in seconds, to drive a known distance of 300 ft. Speed verification was repeated three times.

Application Regime: The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated (acres)	Calculated Application Rate[2] (lb ae/acre)	Reported Application Rate (gal/acre)
Soybean	Spray	9/12/2019 at 11:15	9.58	18.6	0.515	15.4

Data obtained from Appendix B, p. 105 and Appendix B, Table 1, p. 120 of the study report.
[1] Reviewer calculated as calculated application rate (lb a.e./acre) × area treated (acres).
[2] Reviewer calculated as percent of target applied (103%) × target application rate (0.5 lb a.e./acre, Appendix B, Table 1, p. 120).

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3**.

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period
Soybean	18.6	9/12/2019 between 11:15 – 11:33	9/12/2019 between 11:40 – 15:45	Not Applicable	Not Applicable

Data obtained from Appendix B, p. 105; and Appendix B, Table 6, p. 126 of the study report.
[1] Initial air monitoring period is that for perimeter stations. The initial period at the center station was 9/12/2019 between 11:44 – 15:44 (Appendix B, Table 6, p. 125).

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 6.6-7.4 (Appendix B, p. 107; Tables 2-3, pp. 121-122).

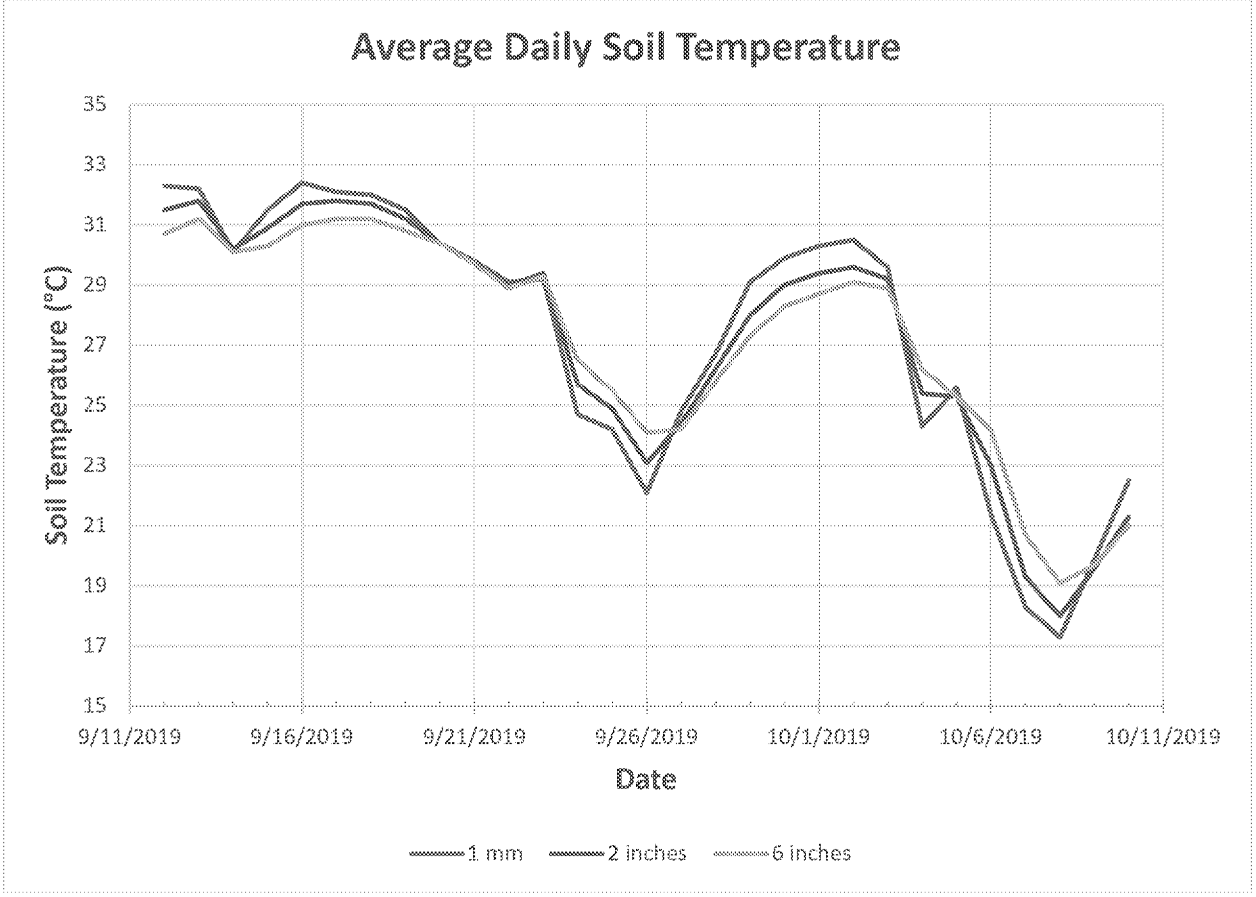
Table 4. Summary of soil properties for the soybean plot

Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm^3)	Soil Composition
Soybean North Field	0-6	Sandy loam	Not Reported	Not Reported	1.26	% Organic Carbon[1] = 0.62% % Sand = 79% % Silt = 10% % Clay = 11%
Soybean South Field	0-6	Loamy sand	Not Reported	Not Reported	1.27	% Organic Carbon[1] = 0.62% % Sand = 83% % Silt = 8% % Clay = 9%

Data obtained from Appendix B, pp. 107, 116, and Appendix B, Tables 2-3, pp. 121-122 of the study report.
[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72. Samples were taken from the north and south of the service road crossing the plot (Appendix B, p. 107; Figure 1, p. 143).

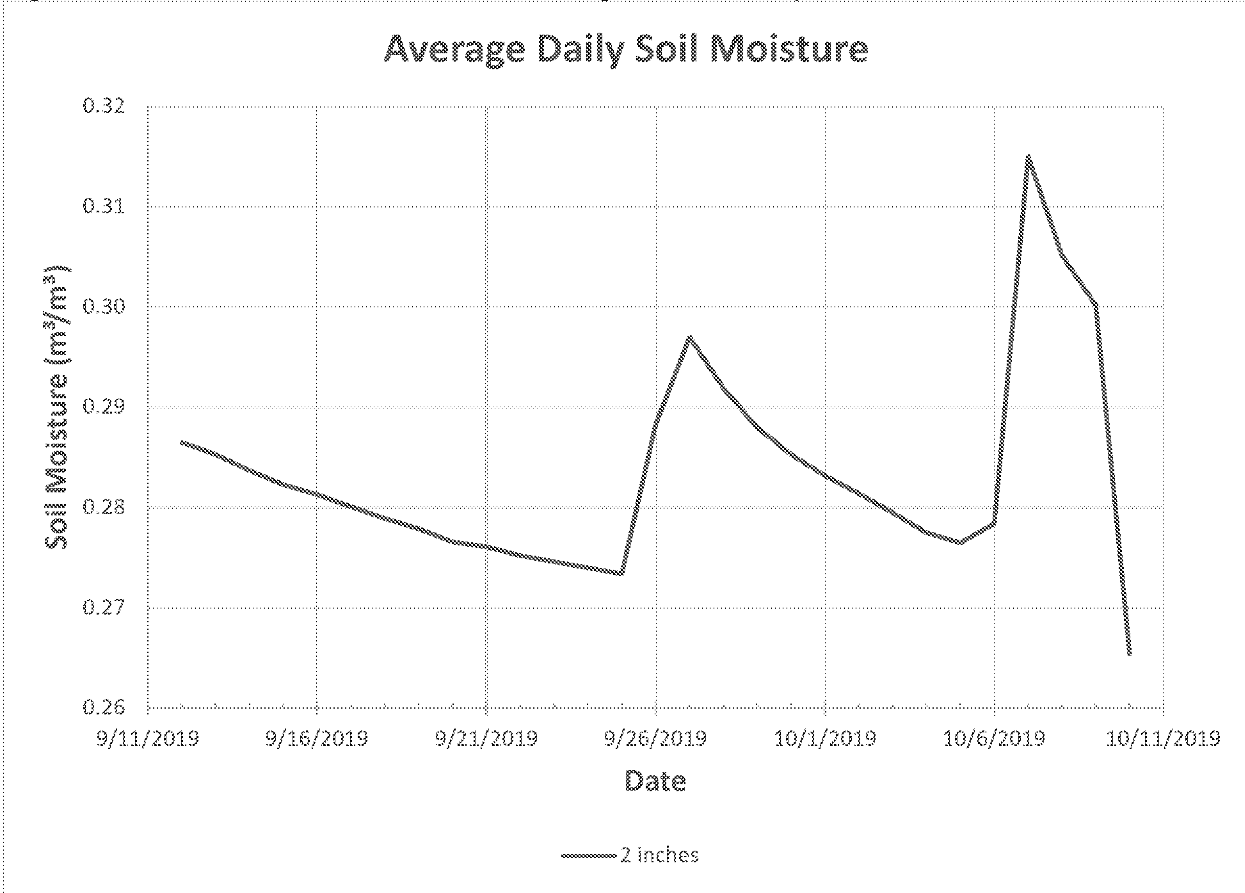
Figures 2 and **3** are plots of soil temperature and soil moisture measured throughout the study.

Figure 2 Soil temperature measured throughout the study



Data obtained from Appendix B, Table 14, pp. 139-140 of the study report.

Figure 3 Soil moisture measured throughout the study



Data obtained from Appendix B, Table 14, pp. 139-140 of the study report.

4. Source Water

Tank mix water was obtained from a nurse tank located at the tank mixing site with water sourced from a well located on the applicator's farm. The pH of the tank mix water was 7.8 as measured at the field, with pH at the analytical laboratory of 8.1, an alkalinity of 163 mg $CaCO_3$/L, and a conductivity of 0.45 mmhos/cm.

5. Meteorological Sampling

Five meteorological stations were used to collect weather data during the study (Appendix B, p. 106).

The 10-meter main meteorological station was located upwind of the test plot (Appendix B, p. 106, and Figure 5, p. 147). The system included a Campbell CR6 data logger and a Campbell Scientific Cell 210 module to remotely monitor data. All parameters were reported at heights of 1.7, 5, and 10 m. The station included sensors for monitoring windspeed and direction (3D anemometer at 10 m and 2D anemometers at 1.7 and 5 m), air temperature, and relative humidity.

A boom height anemometer collected wind speed and wind direction data during application at a height of 51 cm above the crop canopy (Appendix B, p. 106). The anemometer was located *ca.* 3 m downwind of the sprayed area.

The long duration main meteorological station was located upwind of the test plot and recorded data for 28 days post-test substance application (Appendix B, p. 106, and Table 13, pp. 137-138). The station included wind speed and direction sensors (1.76 m), a rain gauge sensor (1.61 m), a temperature/relative humidity sensor (1.27 m), a pyranometer to measure solar irradiation (1.56 m), three soil temperature sensors (depths of 1 mm, 2 inches, and 6 inches), and one soil moisture sensor (depth of 2 inches).

The primary flux meteorological station was deployed outside of the plot prior to and during application and was then moved to the center of the plot, remaining there until after the final drift sample was collected on September 19, 2019 (Appendix B, p. 107). The station included a Campbell CR6 data logger and a Campbell Scientific Cell 210 module to remotely monitor data. The station included sensors for air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy.

A secondary flux meteorological station also recorded air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy (Appendix B, p. 107). The secondary meteorological station was a backup flux meteorological station and was positioned upwind and outside of the sprayed area.

Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 5. Summary of meteorological parameters measured in the field

Field	Minimum Fetch (m)	Parameter	Monitoring heights (m)	Averaging Period
Soybean Plot 10-Meter Main Met. Station	Not Reported	Air temperature	1.7, 5, and 10	1 minute
		Relative humidity	1.7, 5, and 10	1 minute
		Wind speed/wind direction	1.7, 5, and 10	1 minute
Soybean Plot Boom Height Anemometer	Not Reported	Wind speed/wind direction	0.51*	Not Reported
Soybean Plot Long Duration Main Met. Station	Not Reported	Precipitation	1.61	1 minute
		Air temperature	1.27	1 minute
		Relative humidity	1.27	1 minute
		Soil temperature	1 mm, 2 inches, 6 inches	1 minute
		Soil moisture	2 inches depth	1 minute
		Solar radiation	1.56	1 minute
		Wind speed/wind direction	1.76	1 minute
Soybean Plot Primary Flux Met. Station	144.26	Air temperature	0.33, 0.55, 0.9, and 1.5*	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5*	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5*	1 minute
Soybean Plot Secondary Flux Met. Station	Not Reported	Air temperature	0.33, 0.55, 0.9, and 1.5*	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5*	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5*	1 minute

Data obtained from Appendix A, pp. 45-47, 79; Appendix B, pp. 106-107; and Appendix D, Table 8, p. 577 of the study report.
* Denotes height above crop canopy

6. Air Sampling

Two pre-application samples were collected at 0.15 m above the crop surface at the approximate center of the test plot (Appendix B, p. 109). Samples were collected for *ca.* 6 hours on September 10, 2019 from 9:43 to 16:08.

Post-application in-field air samplers were used for flux monitoring for *ca.* 168 hours following application (Appendix B, pp. 109-110). Samplers were placed on a mast in the approximate center of the plot directly following spray application at heights of 0.15, 0.33, 0.55, 0.90, and 1.5 m above the crop surface (crop canopy was approximately 0.51 m). Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. Sample collection for the 0 to 6-hour and 6 to 12-hour intervals were pro-rated based on the time remaining until sunset on the day of application. The samples from these periods represented less than 6 hours of sampling, respectively. Following the 6 to 12-hour interval, sampling was completed on a sunrise-sunset schedule, with consistent morning and evening sampling times.

Off the plot, eight perimeter air monitoring stations were located 1.5 m above the crop canopy and 5 m outside the edge of the plot (Appendix B, p. 110). Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sampling schedule was the same as for the in-field air sampling.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects, two left wind transects, two right wind transects, and two upwind transects. All transects were perpendicular to the edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 120 m in the downwind transects only. Deposition collectors were secured to carboard squares and attached to a horizontal plastic platform at crop height. Initial deposition samples were collected 5 minutes after spray application was completed. Deposition samples were then collected at intervals of 1, 24, 72, 96, 120, 144, and 168 hours post-application (Appendix B, pp. 111-112).

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to dicamba-tolerant soybeans was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the tolerant soybean field and perpendicular to the sprayed field edges of the application area, as well as four transects radiating from the corners of the sprayed field out to a maximum distance of approximately 120 meters (Appendix G, pp. 745-746; Figure 2, p. 773). However, the east downwind corner at 120 m could not be evaluated due to proximity of the road. Height effects and visual symptomology was recorded at 0, 14, and 28 days after spray application of the tank mix. Dicamba-non-tolerant soybean were evaluated at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field. Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, eight upwind control areas were identified and evaluated for plant height.

Plant effects from volatility were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift (Appendix G, pp. 745-746; Figure 3, p. 774). The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology from dicamba volatility. The plastic covers were intended to remain in place for approximately 30 min post-application before permanent removal for the remainder of the study. Transects for volatility only were 20 m long and plant height measurements and visual symptomology ratings were completed at approximately 3, 5, 10, and 20 m from the sprayed area at 0, 14, and 28 days after treatment.

At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points. Plant height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud to the nearest centimeter using a metal metric ruler. Where multiple shoots were present, measurements along the main shoot were taken.

9. Sample Handling and Storage Stability

PUF sorbent tube and deposition filter paper samples were handled with nitrile gloves, which were replaced after the collection of samples and prior to installation of a new sample media for the next sampling interval (Appendix B, p. 108). PUF sorbent tubes and filter papers were placed in pre-labeled conical tubes. Pre-application PUF samples, upwind filter paper samples, and application monitoring samples were stored in separate coolers packed with dry ice and shipped to the analytical lab. Post-application PUF samples, field-exposed spikes, transit stability samples, and downwind, left wind, and right wind filter paper samples were stored in a freezer at *ca.* -20°C freezer prior to shipment. All samples were shipped in coolers on dry ice via FedEx to the analytical test site, Eurofins, in Columbia, Missouri.

All field collected PUF and filter paper samples were extracted within 21 and 22 days, respectively, after collection (Appendix C, p. 263). All field exposed QC and transit stability samples were extracted within 22 days after fortification. All PUF and filter paper samples were analyzed within 2 and 5 days of extraction, respectively, excluding one 96-hr PUF sample analyzed 15 days after extraction. All PUF and filter paper samples were analyzed within 25 and 24 days of sampling, respectively (Appendix C, pp. 439-458). Stability was demonstrated in the study by the recovery of dicamba in fortified field QC and transit stability samples run concurrently with the field samples.

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of PUF collectors and tubing protected from precipitation by ¾ inch diameter PVC pipes (Appendix B, p. 109). SKC AirChek 52 air sampling pumps were used, covered with plastic bags to protect them from precipitation. Pumps were calibrated to a flow rate of 3.000 ± 0.050 L/min and flow was checked at the end of each sampling period.

- Extraction method: The contents of the PUF sorbent tubes were extracted using methanol containing stable-labeled internal standard. The sample was fortified with internal standard, two grinding balls were added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 30 minutes. The cap was removed, and a 1.5 mL aliquot was transferred to a 0.45 µm polypropylene 96-well filter plate with a clean glass-lined polypropylene plate (2 mL) positioned below the filter plate. The sample was evaporated to dryness under nitrogen at 50°C. The sample was reconstituted with 25% methanol in water. The filter plate was covered and mixed on multi-tube vortexer for 2 minutes. The sample was analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, pp. 263, 322-349).

  The filter paper samples were extracted using methanol containing stable-labelled internal standard. The sample was fortified with internal standard, two grinding balls were added to the tube, and 29.9 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 5 minutes. The tubes were then placed in a ≤10°C centrifuge (4500 xg for 5 minutes) and spun to clear suspended materials from the liquid column and form a solid pellet. The cap was removed and a 0.35 mL aliquot was transferred to a clean 96-well filter plate with a clean, glass-lined polypropylene plate positioned below the filter plate. The plates were then placed in a ≤10°C centrifuge (1500 xg for 1 minute) and spun until liquid passed through the plate. The solution was analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 350-369).

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying 18 replicate fortification samples at each of three fortification levels (0.3 ng/PUF, 3 ng/PUF, and 60 ng/PUF; Appendix C, pp. 340-344). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries for primary ion transitions were 89%, 94%, and 90% at 0.3, 3, and 60 ng/PUF, respectively. Average recoveries for secondary ion transitions were 93%, 97%, and 98% at 0.3, 3, and 60 ng/PUF, respectively. No independent laboratory validation is provided. For primary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.094 ng/PUF (Appendix C, p. 341). For secondary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.065 ng/PUF. During the study, the LOQ was 1.0 ng/PUF (p. 15).

  Method validation was achieved by fortifying 6 replicate fortification samples at each of three fortification levels (0.005, 0.10, and 4.8 µg/filter paper; Appendix C, pp. 364).

Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level. Average recoveries were 81%, 117%, and 104% at 0.005, 0.10, and 4.8 µg/filter paper, respectively. No independent laboratory validation is provided, although results from Field Deposition Study REG-2015-004 confirmed the results. The LOQ during method validation was 0.005 µg/filter paper (Appendix C, p. 350). During the study, the LOQ was 0.005 µg/filter paper (p. 15).

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.15 to 75 ng/PUF (Appendix C, p. 328). Concentrations were 0.15, 0.225, 0.3, 0.75, 1.5, 2.25, 3, 7.5, 15, 22.5, 30, and 75 ng/PUF. Analyst® software was used to derive the calibration curve using a weighted linear curve (1/x; Appendix C, pp. 334 and 387).

  Calibration standards were prepared at concentrations ranging from 0.0015 to 6 µg/filter paper (Appendix C, p. 355). Concentrations were 0.0015, 0.003, 0.0075, 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, and 6 µg/filter paper. Analyst® software was used to derive the calibration curve using a weighted quadratic curve (1/x; Appendix C, pp. 360 and 405).

11. Quality Control for Air Sampling

Lab Recovery: 14 of 23 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 390-391). All laboratory spike recoveries are within the range of 85-127%. Laboratory spike samples were prepared at fortification levels of 1 ng/PUF (11 samples) and 60 ng/PUF (12 samples). Average recoveries were 106% and 106% at 1 ng/PUF and 60 ng/PUF, respectively (Appendix C, p. 391).

Field blanks: Two pre-application samples were collected from the center of the test plot from 9:43 to 16:08 on September 10, 2019, two days before application (Appendix B, p. 109). Dicamba was detected in pre-application samples at 2.53 and 3.97 ng/PUF (Appendix B, p. 117).

Control samples from the field spike analysis did not contain detectable levels of dicamba (Appendix B, p. 117 and Appendix C, Table 9, p. 282).

Field Recovery: Nine 6-hour and nine 12-hour field spike samples were collected at concentration levels of 3, 10, and 30 ng/PUF. A total of six field spikes were prepared at each concentration level. Most field spike recoveries are within the acceptable range with overall recoveries of 96% to 125% at 3 ng/PUF, 90% to 110% at 10 ng/PUF, and 98% to 112% at 30 ng/PUF (Appendix B, p. 117; Appendix C, Table 8, p. 281).

Travel Recovery: Three transit stability PUF samples were fortified at 30 ng/PUF and placed on dry ice along with three unfortified control samples (Appendix B, p. 114). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 99% to 108% (Appendix C, Table 9, p. 282).

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries ranging from 100% to 114% (Appendix C, pp. 390-391). The highest dicamba amount measured on a PUF sample (excluding laboratory and field spikes) was 29.9 ng/PUF (Appendix C, pp. 394-403) which is *ca.* 50% of the highest fortification level, indicating that dicamba loss due to breakthrough is unlikely.

12. Quality Control for Deposition Sampling

Lab Recovery: 47 of 60 laboratory spike recoveries are within the acceptable range of 90-110%. All laboratory spike recoveries are within the range of 71-112%. Laboratory spike samples were prepared at fortification levels of 0.005 μg/filter (27 samples), 5 μg/filter (27 samples), and 50 μg/filter (6 samples). Average recoveries were 90%, 101%, and 101% at 0.005 μg/filter, 5 μg/filter, and 50 μg/filter, respectively. Control samples from the field spike analysis did not contain detectable levels of dicamba (Appendix C, p. 408-411).

Travel Recovery: Five transit stability filter paper samples were fortified at 0.05 μg/filter paper and placed on dry ice along with five unfortified control samples (Appendix C, p. 300). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 94% to 98%.

13. Application Verification

Four application monitoring sampling stations, each consisting of four 12.5 cm diameter Whatman #3 filter paper samples, were positioned in the spray area (Appendix B, p. 109). The stations were positioned to capture different portions of the spray boom and different spray nozzles. The average recovery relative to the target was 101% (Appendix B, p. 116; Appendix B, Table 15, p. 141; and Appendix C, p. 377).

Spray application rates were automatically maintained by the sprayer using a variable rate controller (Appendix B, p. 115). The application rate was assumed to be 100% of the target rate, and pass times were not used to calculate an application rate. Based on Climate FieldView™ software application data, the actual application rate was 103% of the target rate (Appendix B, Table 1, p. 120).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix B, p. 108).

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated based on the calculated flux rates and relevant meteorological data. U.S. EPA's AERMOD model (version 18081) was used to estimate deposition, while the Probabilistic Exposure and Risk model for Fumigants

(PERFUM2, version 2.5) was used to estimate air concentrations (Appendix E, p. 608). Three sets of estimates were calculated, using meteorological data for Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas (Appendix E, p. 608). The reviewer used PERFUM version 3.2 to estimate air concentrations using the same meteorological data.

The maximum flux predicted by any method for each period was chosen to represent that period. Periods were then mapped onto hours of the day (1- 24), where the maximum flux rate for each hour was then chosen to represent that hour, regardless of the day from which it was collected. In cases where two periods occurred in a single hour, a weighted average of the flux rates was used. The 24-hour flux profile for the first two days were used as inputs for PERFUM2 and the average flux rate and as adjustment factors for input into AERMOD. The reviewer and study author flux rates were slightly different, particularly where weighted averaging occurred. However, they did not impact the overall modeling conclusions.

Wet, dry, and total deposition estimates were made at 10 distances from the field (5, 10, 20, 30, 40, 50, 75, 100, 125, and 150 m; Appendix E, pp. 610). For the fluxes from the soybean plot at a distance of 5 m from the edge of the field, maximum 24-hour average total (dry+wet) deposition ranged from 8.56 to 9.93 $\mu g/m^2$ (Appendix E, Table 7, pp. 623-624). 90th percentile total deposition ranged from 4.38 to 5.80 $\mu g/m^2$.

Modeled dicamba air concentrations were calculated at 4 distances from the field (5, 10, 25, and 50 m; Appendix E, pp. 609-610). Modeled 95th percentile 24-hour air concentrations ranged from 15.8 to 25.9 ng/m^3 at 5 m from the edge of the treated field and 11.4 to 19.2 ng/m^3 at 50 m from the edge of the field (Appendix E, Table 6, p. 622).

The reviewer was able to confirm the modeling conclusions both for deposition and air concentrations. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Modeled 95th percentile 24-hour air concentrations were slightly higher (30-67 ng/m3), but comparable, than those achieved for the North Carolina, Illinois, and Texas modeling results.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 18081) and a unit flux rate of 0.001 $g/m^2 \cdot s$ to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. However, if, after regression analysis, the linear regression did not result in a statistically significant relationship, instead of rerunning the regression by forcing the intercept through zero, the spatial relationship was removed by sorting both the measured and modeled air concentrations (independently) in ascending order, then redoing the regression, with the final flux estimate calculated as the slope of this alternative regression multiplied by the nominal flux. If the sorted regression was also not statistically significant, the ratio of the sum of the measured concentrations to the sum of the modeled concentrations was multiplied by the nominal flux to get the final flux estimate.

Aerodynamic Method

The aerodynamic method, also referred to as the "flux-gradient" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

Equation 1
$$P = \frac{k^2(\Delta\bar{c})(\Delta\bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman's constant (dimensionless ~0.4), $\Delta\bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta\bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

Equation 2 $$Flux = \frac{-(0.42)^2 (c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL)stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

Equation 3 $$R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\frac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + (u_{ztop} - u_{zbottom})^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$\phi_m = (1 + 16R_i)^{0.33}$ and $\phi_p = 0.885(1 + 34R_i)^{0.4}$

if $R_i < 0$ (for Convective/Unstable IBL)
$\phi_m = (1 - 16R_i)^{-0.33}$ and $\phi_p = 0.885(1 - 22R_i)^{-0.4}$

The minimum fetch requirement that the fetch is 100 times the highest height of the air sampler for this method to be valid was not satisfied at for any of the sampling periods. Average fetch distances ranged from 144 to 166 m, while the minimum fetch distance was 170 m (the highest height of the samplers was 1.7 m). The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

Equation 4 $$P = \frac{1}{x} \int_{Z_0}^{Z_p} \overline{c}\overline{u} \, dz$$

where P is the volatile flux in units of µg/m^2·s, $\bar{c}$ is the average pesticide residue concentration in units of µg/m^3 at height Z in units of meters, $\bar{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters, and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 3 is simplified as follows in equation 5 (Yates, 1996):

Equation 5 $$P = \frac{1}{x}\sum_{Z_0}^{Z_P}(A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

Equation 6 $$Z_P = \exp\left[\frac{(0.1 - D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface roughness length was below the maximum surface roughness requirement of 0.1 meters for most monitoring periods, except for Periods 7, 9, 11, and 13, when the surface roughness was 0.11 to 0.12. All of these periods were overnight periods.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 5.50 prior to application.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m^2·s)	Notes	Registrant (µg/m^2·s)	Notes
1	9/12/19 11:40 – 15:45	4:05	0.001154	Regression	0.001154	A
2	9/12/19 15:26 – 19:43	4:17	0.001503	Regression, no intercept	0.002981	B
3	9/12/19-9/13/19 19:24 – 8:10	12:46	0.000150	Regression, no intercept	0.000031	C
4	9/13/19 7:54 – 18:40	10:46	0.000269	Regression	0.000269	A
5	9/13/19-9/14/19 18:26 – 8:08	13:42	0.000057	Regression	0.000057	A
6	9/14/19 7:52 – 18:40	10:48	0.000108	Regression	0.000108	A

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Notes	Registrant (µg/m²·s)	Notes
7	9/14/19-9/15/19 18:26 – 8:00	13:34	0.000016	Regression	0.000016	A
8	9/15/19 7:42 – 18:37	10:55	0.000188	Regression	0.000188	A
9	9/15/19-9/16/19 18:13 – 8:07	13:54	0.000035	Regression, no intercept	0.000017	C
10	9/16/19 7:42 – 18:23	10:41	0.000082	Regression, no intercept	0.000035	C
11	9/16/19-9/17/19 18:08 – 7:54	13:46	0.000017	Regression	0.000017	A
12	9/17/19 7:40 – 18:19	10:39	0.000080	Regression	0.000080	A
13	9/17/19-9/18/19 18:06 – 7:50	13:44	0.000012	Regression, no intercept	0.000014	C
14	9/18/19 7:32 – 18:27	10:55	0.000050	Regression	0.000050	A
15	9/18/19-9/19/19 18:12 – 8:00	13:48	0.000004	Regression	0.000009	C

Data obtained from Appendix B, Table 6, p. 126 and Appendix D, Table 6, p. 575 of the study report.
Notes
A The spatial regression method was used to calculate the flux estimate for the sampling period.
B The ratio method was used to calculate the flux estimate for the sampling period.
C The sorted regression method was used to calculate the flux estimate for the sampling period.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Registrant (µg/m²·s)	Empirical Flux Determination Method*	Notes
1	9/12/19 11:44 – 15:44	4:00	0.000477 0.002117	0.000477 0.001913	IHF AD	
2	9/12/19 15:47 – 19:33	3:46	0.000662 0.001543	0.001277 0.000763	IHF AD	
3	9/12/19-9/13/19 19:35 – 8:03	12:28	0.000939 0.000117	0.000936 0.000076	IHF AD	
4	9/13/19 8:05 – 18:34	10:29	0.000158 0.000321	0.000155 0.000297	IHF AD	
5	9/13/19-9/14/19 18:35 – 7:58	13:23	0.000066 0.000071	0.000038 0.000068	IHF AD	
6	9/14/19 7:58 – 18:34	10:36	0.000057 0.000310	0.000056 0.000330	IHF AD	

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Registrant ($\mu g/m^2 \cdot s$)	Empirical Flux Determination Method*	Notes
7	9/14/19-9/15/19 18:37 – 7:49	13:12	0.000027 0.000032	0.000052 0.000017	IHF AD	
8	9/15/19 7:50 – 18:19	10:29	0.000072 0.000285	0.000071 0.000277	IHF AD	
9	9/15/19-9/16/19 18:29 – 7:56	13:27	0.000029 0.000028	0.000052 0.000010	IHF AD	
10	9/16/19 7:56 – 18:14	10:18	0.000011 0.000074	0.000011 0.000052	IHF AD	
11	9/16/19-9/17/19 18:15 – 7:46	13:31	0.000163 0.000000	0.000157 0.000000	IHF AD	
12	9/17/19 7:48 – 18.14	10:26	0.000009 0.000029	0.000009 0.000027	IHF AD	
13	9/17/19-9/18/19 18:15 – 7:39	13:24	0.000007 0.000007	0.000003 0.000006	IHF AD	
14	9/18/19 7:40 – 18:16	10:36	0.000080 0.000025	0.000076 0.000026	IHF AD	
15	9/18/19-9/19/19 18:17 – 7:52	13:35	0.000003 0.000006	0.000003 0.000005	IHF AD	

Data obtained from Appendix B, Table 6, p. 125; Appendix D, Table 8, p. 577; and Appendix D, Table 10, p. 579 of the study report.
*Methods legend: ID = Indirect Method, AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.

The maximum flux rate calculated by the study authors using the Indirect and Integrated Horizontal Flux methods occurred during the second sampling period after application, and during the first sampling period for the Aerodynamic method. Maximum flux rates estimated by the study authors were 0.002981 $\mu g/m^2 \cdot s$, 0.001277 $\mu g/m^2 \cdot s$, and 0.001913 $\mu g/m^2 \cdot s$ for the Indirect, Integrated Horizontal Flux, and Aerodynamic methods, respectively (Appendix D, pp. 556-558). The reviewer estimated a different flux rate for the second sampling period for the Indirect method, based on the regression methods. The reviewer also estimated a different flux rate for the second sampling period for the Integrated Horizontal Flux method. The slopes and intercepts for this period were estimated by the reviewer using sampling heights adjusted to account for the crop height (20 cm), whereas it looks like the sampling heights may not have been adjusted by the study authors for this period.

R-squared values for the linear regressions of modeled and measured air concentrations in the indirect method ranged from 0.32 for period 3 to 0.934 for period 5 (Appendix D, Table 6, p. 575). Study authors used spatial or sorted regressions were used to estimate flux during all periods except period 2, which used the ratio method. The reviewer used a regression or regression with an intercept of 0 for all sampling periods.

R-squared values in log-linear vertical profiles of wind speed were generally high with all r-squared $\geq$0.974 (Appendix D, Table 8, p. 577 and Appendix D, Table 10, p. 579). R-squared values in log-linear vertical profiles of concentration were low for periods 3 (0.649), 11 (0.066), 12 (0.667), 14 (0.127), and 15 (0.696).

R-squared values in log-linear vertical profiles of temperature were less than 0.7 for all periods. The reviewer confirmed this trend, but it is unclear if the poor regressions were the result of incorrect assignment of sampling values with height. An analysis of the temperature with height using the secondary flux meteorological station indicated a good fit for temperature with height, with the r-squared values ranging from 0.01 to 0.98, with five periods below an r-squared of 0.7 (Periods 3, 5, 9, 11, and 13), all of which were overnight periods. As such, the reviewer used the data from the secondary flux meteorological station.

C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were detected at a maximum fraction of the applied deposition of 0.004806 at 3 m from the field within the first hour after application (Appendix F, Table 2, pp. 658-675). Dicamba residues were not detected in any of the upwind or right wind samples within the first hour after application. **Figures 4** and **5** depict the deposition fractions and the reviewer-predicted spray drift curves for the downwind and left wind transects, respectively, within the first hour after application.

To develop the deposition curves, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

Study authors derived deposition curves using four non-linear regression models for each transect (Appendix F, p. 652). For the one-hour sampling period, the best fit models were the exponential with intercept model (downwind transect A and left wind transect A) and power with coefficient model (downwind transects B and C and left wind transect B; Appendix F, Table 3, pp. 680-681). The curves were similar to those generated by the reviewer.

Estimated distances from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) were 9.98 m (7.07 to 15.64 m for the three transects) and 10.24 m (10.23 to 10.25 m for the two transects) in the downwind and left wind directions, respectively, using the reviewer-developed curves and ranged from 6.9 to 15.0 m in the downwind direction and 5.5 to 18.4 m in the left wind direction for the study author developed curves (Appendix F, pp. 654).

Figure 4 Spray Drift Analysis for Downwind Transects – 1 Hour

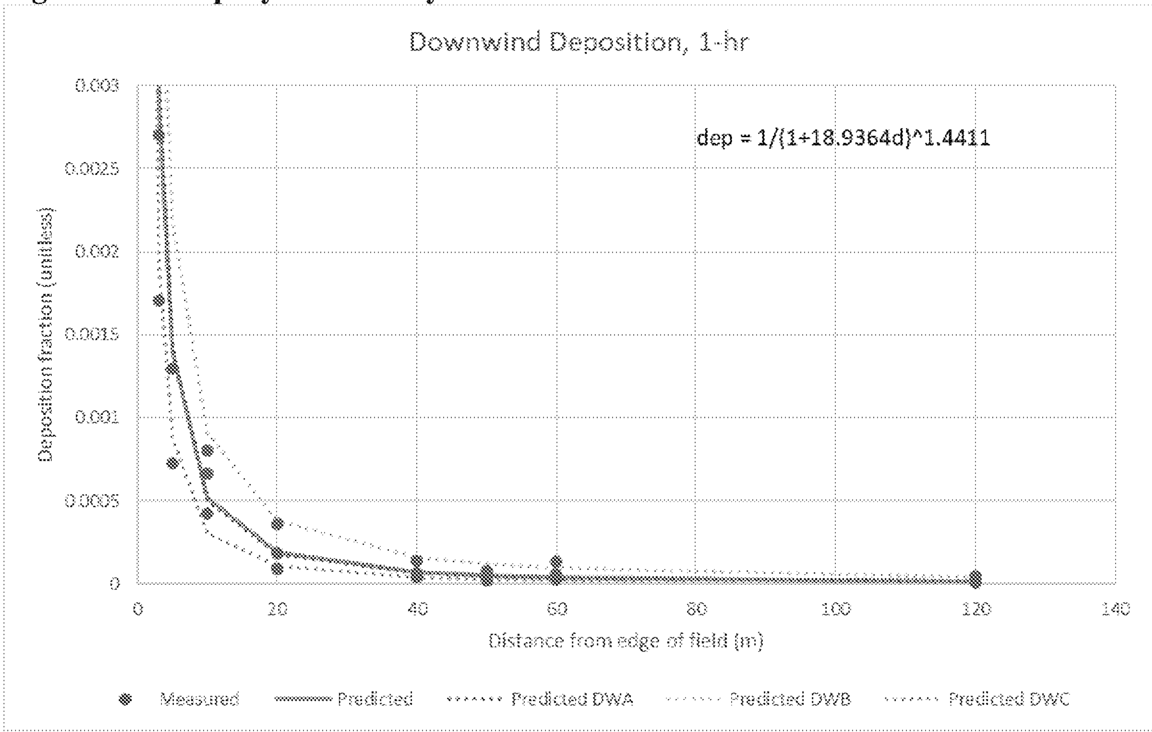
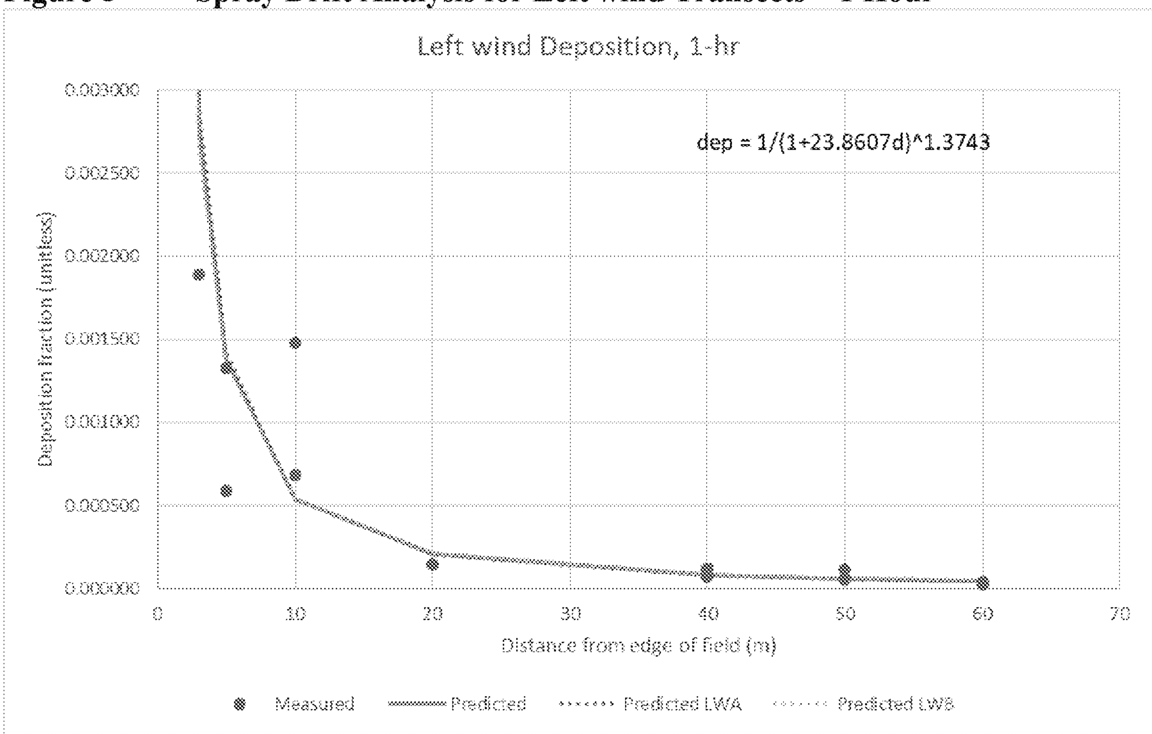


Figure 5 Spray Drift Analysis for Left wind Transects – 1 Hour



D. Plant Effects Measurements

Because there is significant uncertainty as related to the field wide observed VSI, including controls, this section is limited to just providing the plotted data. See executive summary for more discussion.

Figure 6: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for field corner transects (N,S,E,W).

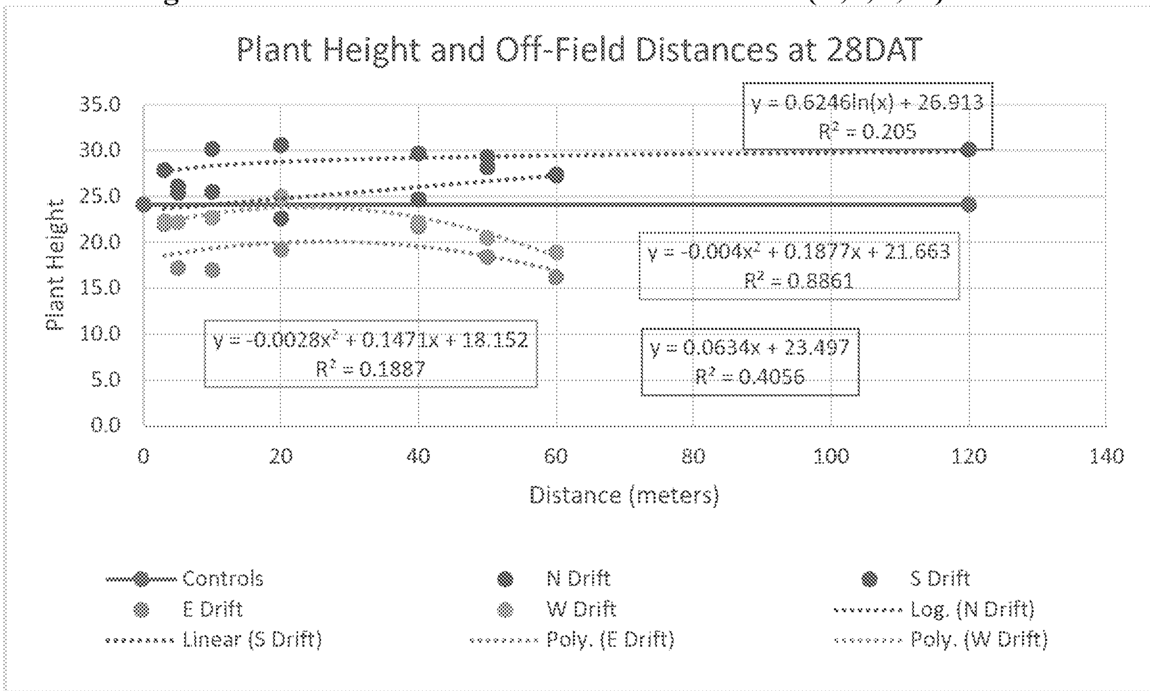


Figure 7: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for the treated area for field corner transects (N,S,E,W).

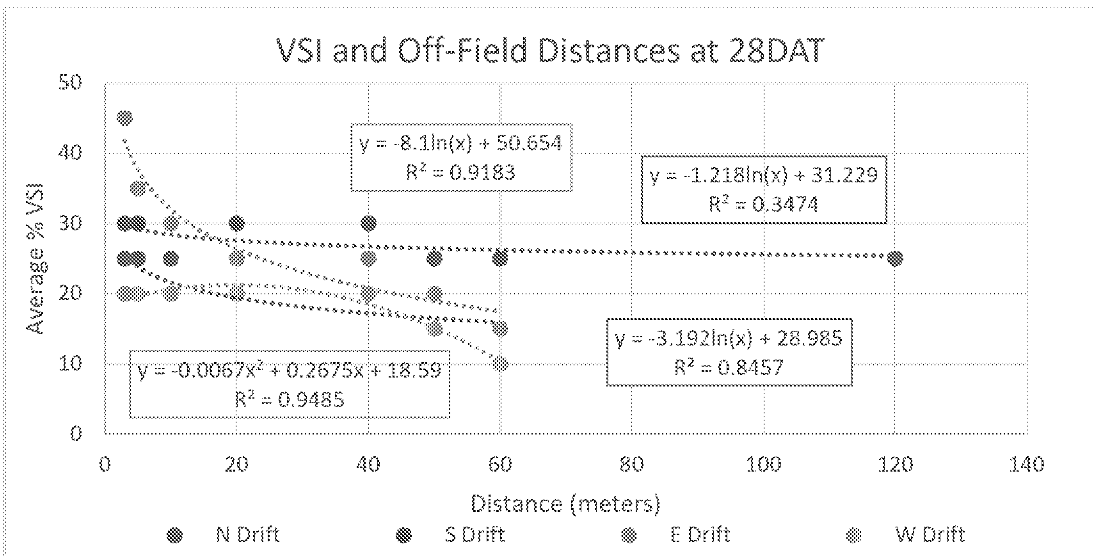


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Figure 8: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Right Wind" transects.

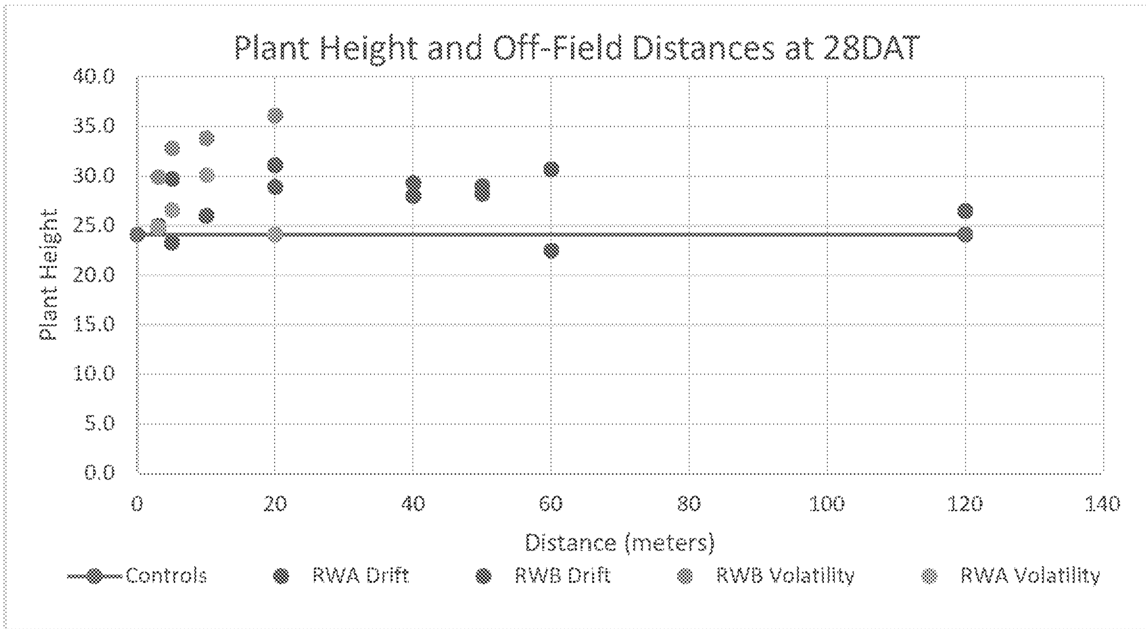


Figure 9: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Right wind Transects".

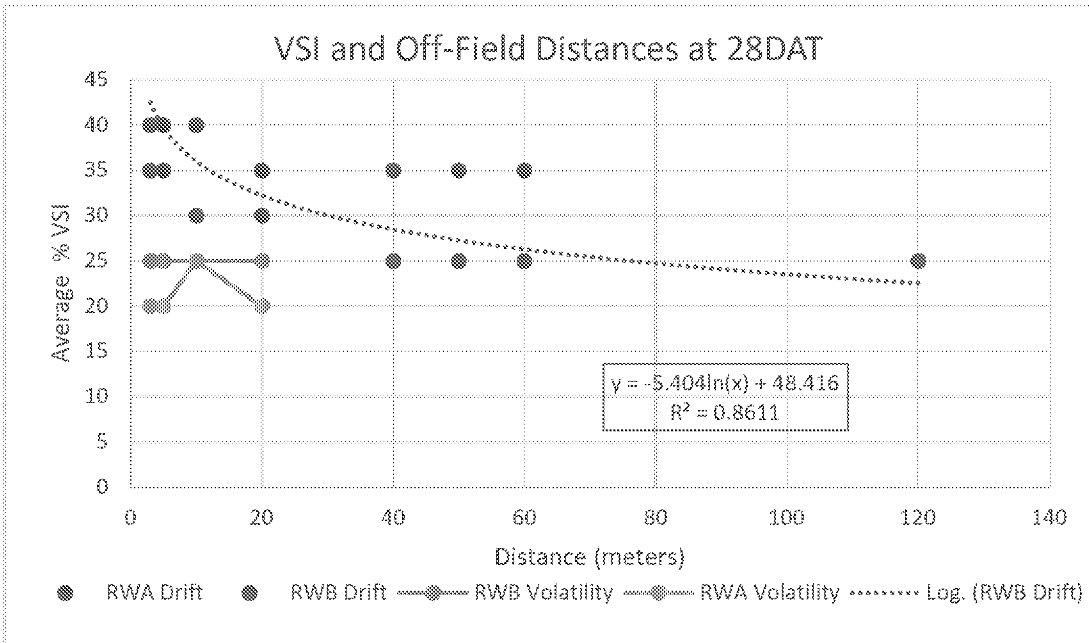


Figure 10: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" transects.

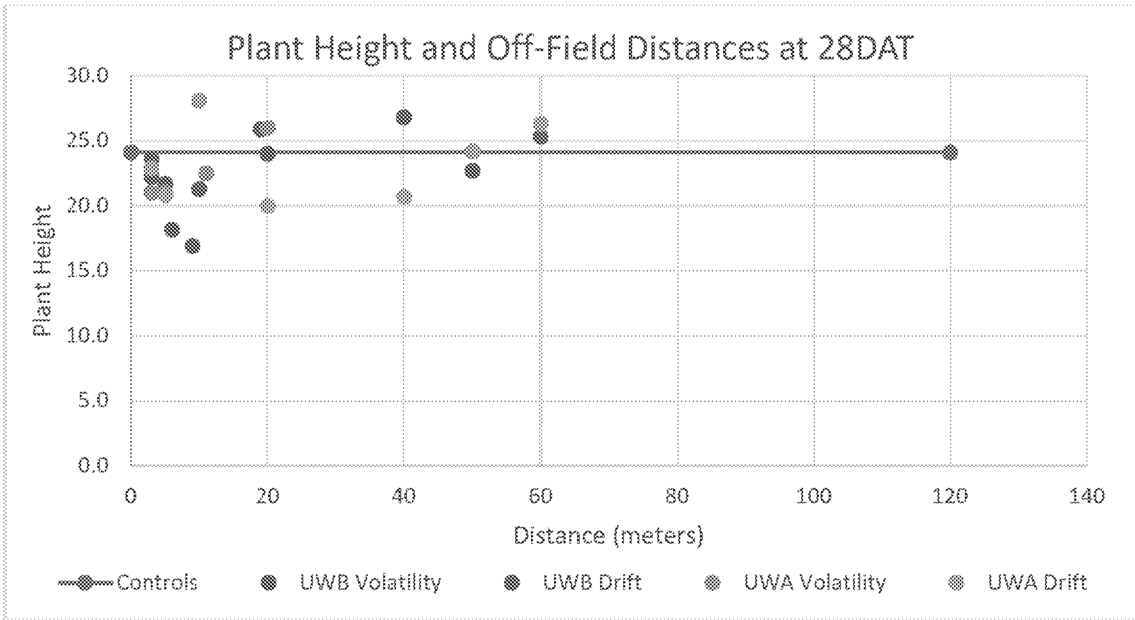


Figure 11: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up wind Transects".

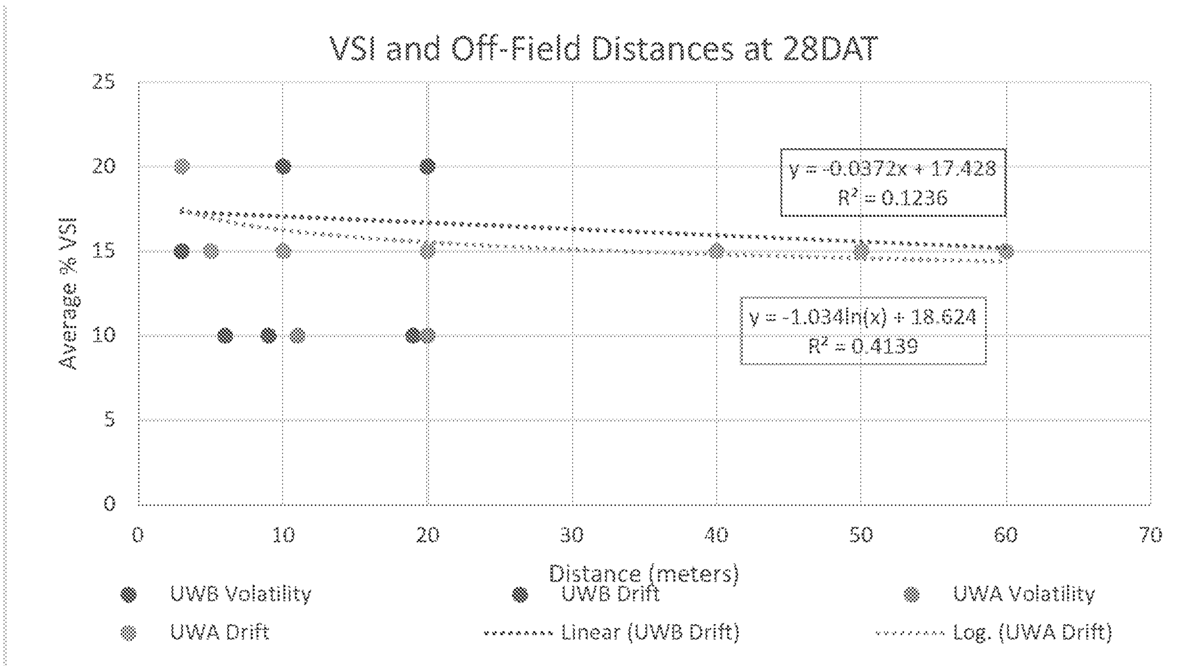


Figure 12: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind" transects.

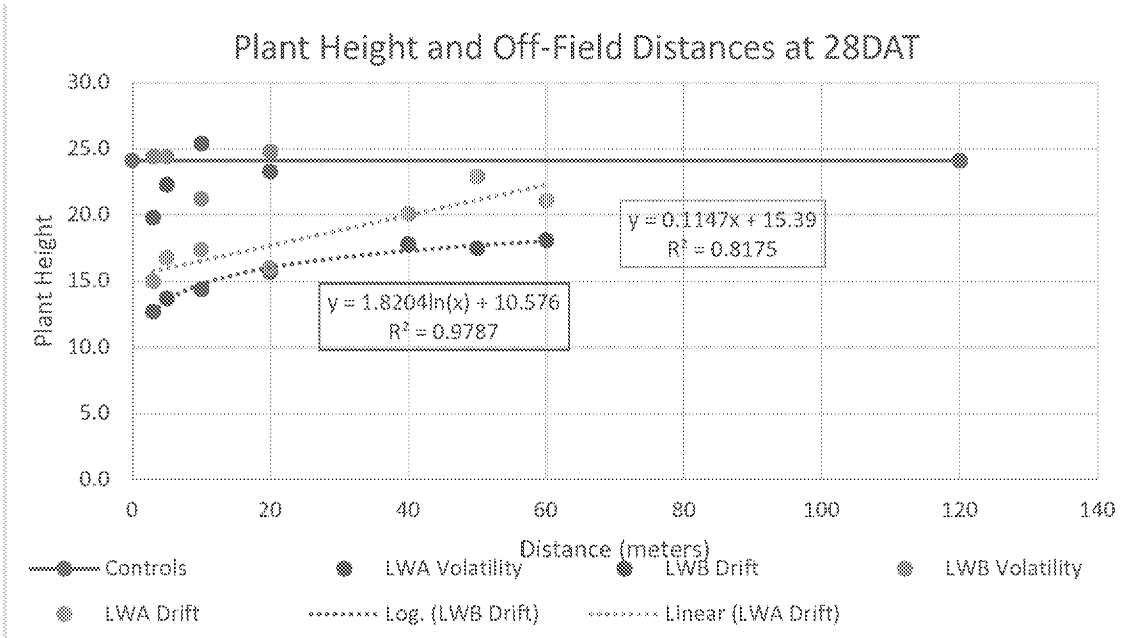


Figure 13: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left wind Transects".

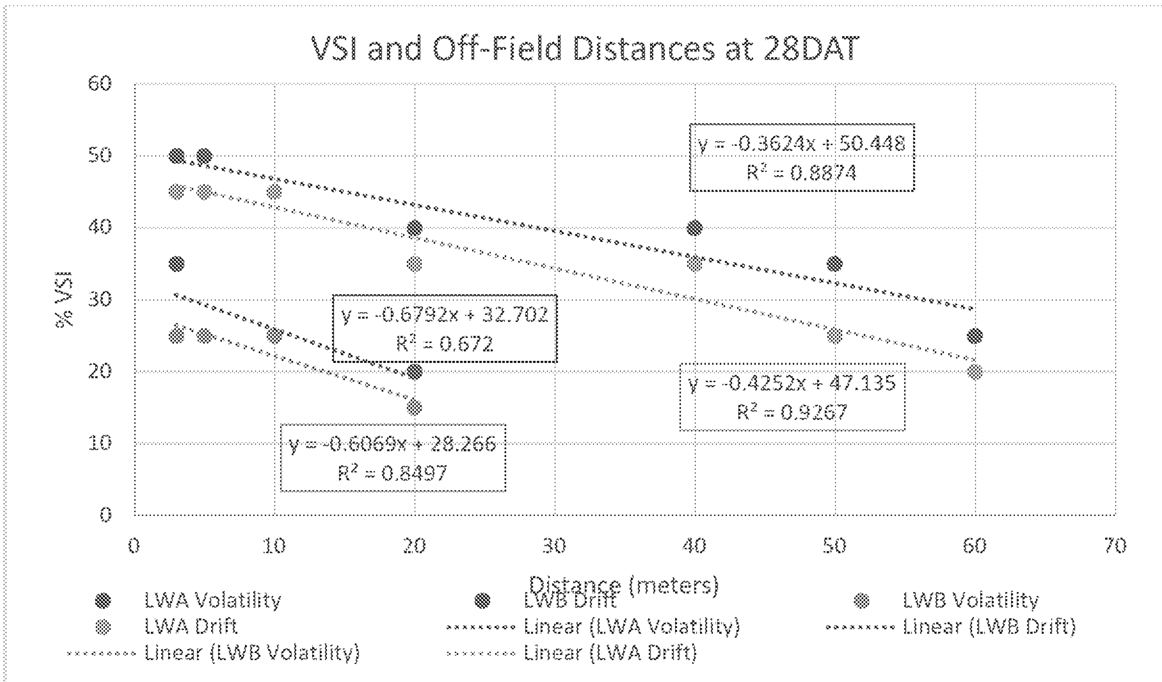


Figure 14: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Down Wind" transects.

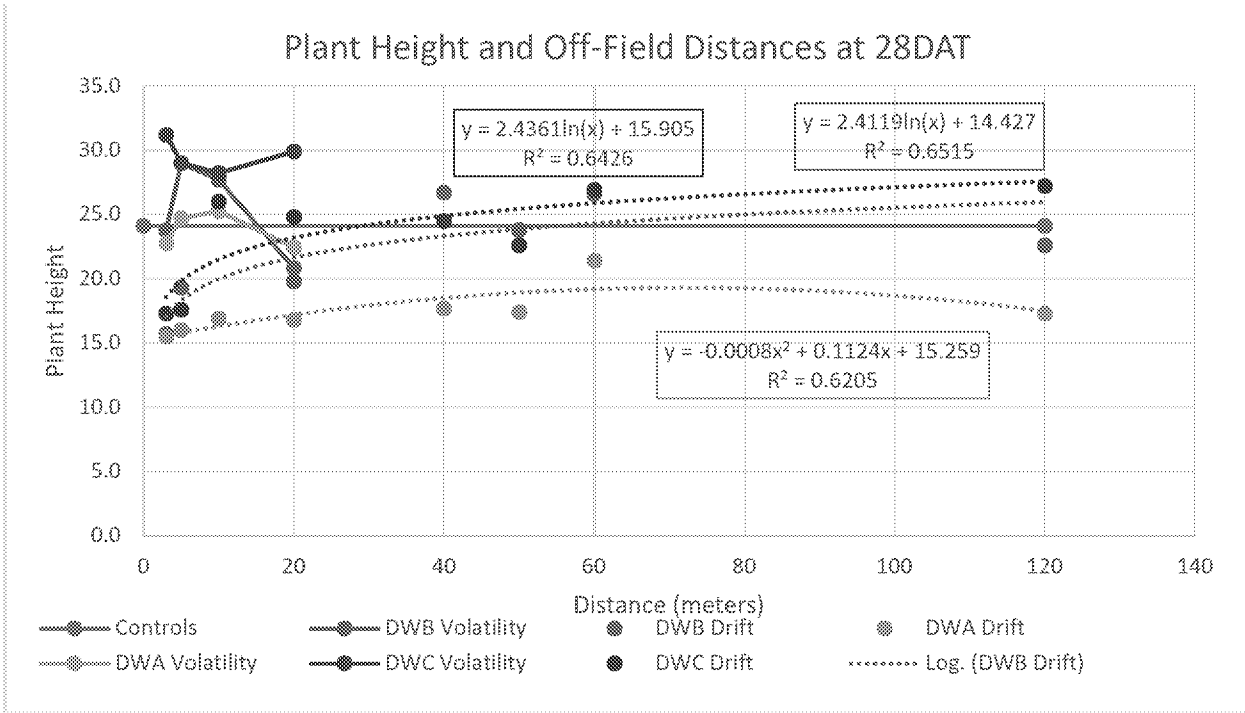
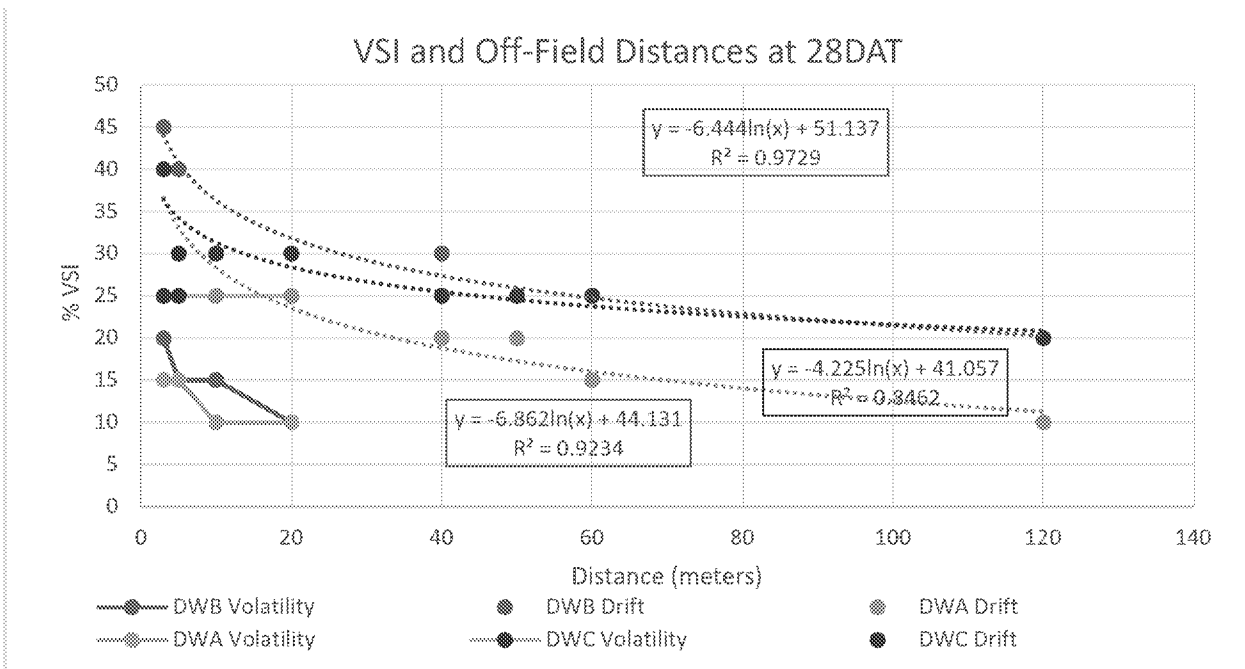


Figure 15: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Down wind Transects".



III. Study Deficiencies and Reviewer's Comments

1. The registrant included the use of an approved buffering agent in the tank mix, potentially to mitigate volatility. While the addition of a neutral buffering agent is permitted on the label, its use was never discussed in the submitted protocol and may have reduced the volatility one would expect to observe in an application that did not include the agent.

2. The registrant used a different approach to calculate Z_p, the top of the concentration plume, than that recommended by EPA when calculating volatilization flux rates using the Integrated Horizontal Flux method (Appendix D, p. 553). The registrant used:

$$Z_p = \exp\left(\frac{-D}{C}\right)$$

   C and D are the slope and intercept of the log-linear concentration regression and removed the 0.1 from the equation. The 0.1 represents the concentration at the top of the plume, which is a carryover from the use of this technique for estimating flux rates for fumigants, which typically have much higher concentrations than those anticipated for semi-volatile chemicals like dicamba. The revised equation is acceptable to the reviewer and does not significantly impact the estimate of flux rates.

3. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to test site observations, slope estimates, pesticide and crop history, soil taxonomy, application summary and spray rate data, and study weather data (p. 3).

4. Dicamba was detected in two pre-application samples at concentrations (2.53 ng/PUF and 3.97 ng/PUF) greater than the LOQ (1 ng/PUF; Appendix C, Table 6, p. 274).

5. The first air monitoring period started after the conclusion of application.

6. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

7. When conducting the indirect flux rate analysis, study authors removed samples from the analysis when the dicamba was detected below the LOD (0.3 ng/PUF) for two of the sampling periods but retained samples that had no observable peak or observed residues. Samples below the LOD should be retained as well.

8. Minimum fetch requirements were not always met for the aerodynamic method, but this is not expected to significantly impact the derivation of the flux rates.

9. The soybean stand was reported to be patchy in certain areas across the field due to environmental conditions (heavy precipitation events; p. 14).

10. Soil was characterized (Appendix B, pp. 107, and Appendix B, Tables 2-3, pp. 121-122), but no taxonomic classification was provided. The custom soil resource report indicated that the area was predominantly Wardell loam (53.3% of area of interest) and Gideon clay loam (33.4% of area of interest; Appendix B, pp. 167-187).

11. Soil characterization (texture, bulk density and organic matter content) were reported at only a single depth of 0-6 inches (Appendix B, Tables 2-3, pp. 121-122).

Study Deficiencies: Plant Effects

1. The study author reported that visible injury resembling dicamba injury was observed on soybean plants in all transects at both post-application measurement events, including controls (p. 752). A baseline dicamba injury of *ca.* 15% was observed beginning on day 14 post-application across the entire field, downwind and leftwind transects had higher symptomology than upwind. The study author did not further characterize or describe the visible injury or quantify the 'higher' symptomology in the downwind and leftwind transects. The study author noted that pre-application dicamba residues detected in the air samples (2.53-3.97 ng/polyurethane foam (PUF) collectors in the center of the application area) coupled with the field-wide injury observed post-application may indicate plants evaluated in this study were 'likely' exposed to dicamba from a source other than the test substance application. The study author presented no additional details or investigation supporting an off-field source of dicamba.

   The reviewer notes that pre-application residues in polyurethane foam air samples may be due to off-site source, contaminated equipment, or cross-contamination during handling, transport or laboratory error. There is no evidence provided that conclusively supports or eliminates the study author assumption of an off-site source.

   The weather data indicate winds were primarily from the west/southwest during the application and the first hour after application, and from the south during the first day after application, and that the winds were a bit stronger in first hour after application than most of the rest of the study period (Figures 1-9, pp. 690-698). Additionally, winds blew from the northwest on day two following application. These wind directions and speeds, along with significant soybean height inhibitions observed in the downwind transects (DW and LW), suggest that injury in the downwind and leftwind transects are, in fact, due to application of the test material.

   On subsequent days after application, warm daytime temperatures, and light, variable wind may have contributed to more widespread exposure to the test material over the entire test area. Also, although the control plot was placed upwind of the treatment field, it is possible the control plot was not located far enough from the treatment location to prevent exposure.

2. The study author identified thirty one plants across all transects that did not pass the upper and lower maximum/minimum height algorithm (Section 2.4.2.1; Table 2, p. 751) for selecting representative plants within a transect. These plants were identified as outside the acceptance limit (outliers) and were excluded from any further analysis except the summary statistics tables and graphs. The study author also calculated effects based on fit to piecewise non-linear curves, which included individual transects DWA, LWB, RWA, ND and UWB; the study author did not compare height to control plants in this modeling. The reviewer analyzed the entire height data set for each transect and compared data to plants in the control field.

3. Following application for both the volatility and spray drift portions of the study, the study author notes that, "At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points" (Appendix G, p. 746).

   OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. The reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

4. A pipe leak in the center pivot well throughout the study was observed to have caused water to pool on the northwest side of the field (right wind transects). Subsequent growth effects due to flooding of the test fields were reported. The variable impact of the flooding on plant growth may have additionally confounded test results.

5. Several transects had plots which had measured less than 10 plants as recommended EFED during protocol review. Furthermore, several plots failed have any plant data reported due to poor germination.

6. The types of phytotoxic symptoms observed were not described. Therefore, it is assumed that all reported VSI is attributable to dicamba related injury.

7. The study author did not provide historical germination rates for the soybean varieties planted.

8. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported. However, a map of the field and test area (Appendix G: Figure 2) provided an approximation of the location.

9. Pesticides applications to the treatment field and test plots in 2019 were not reported.

10. The physico-chemical properties of the test material were not reported.

11. The Beck's 4628FP variety of soybean that was planted in the test plots for both the volatility and spray drift study, is a non-Dicamba tolerant soybean. This variety was also

selected because of its glyphosate-tolerance. The study author did not address the potential for the genetic modifications that made this soybean variety glyphosate-tolerant as providing some degree of dicamba tolerance. Any degree of dicamba tolerance could mask treatment effects.

IV. **References**

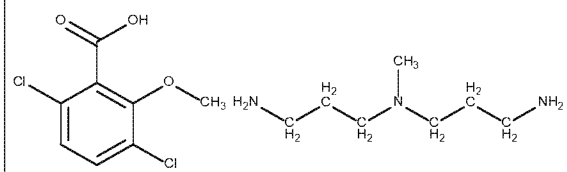
Gavlick, W. (2016). *Determination of a No Effect Crop Response as a Function of Dicamba Vapor Concentration in a Closed Dome System*. Monsanto Company. MSL0028204.

US EPA (2013). *Data Evaluation Report on the Toxicity of Clarity 4.0 SL (AI: Dicamba) to Terrestrial Vascular Plants: Vegetative Vigor*. United States Environmental Protection Agency, Washington D.C. MRID 47815102.

US EPA. (1998). *Spray Drift Test Guidelines, OPPTS 840.1200 Spray Drift Field Deposition*. United States Environmental Protection Agency, Prevention, Pesticides, and Toxic Substances. EPA 712-C-98-112.

US EPA. (2012). *Field Volatility Study Review Guide*. United States Environmental Protection Agency.

DER ATTACHMENT 1. Dicamba BAPMA and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba BAPMA (N,N-Bis-(3-aminopropyl)methyl amine salt of dicamba; BAS 183 22 H; Dicamba-biproamine)	**IUPAC:** 3,6-Dichloro-o-anisic acid - N-(3-aminopropyl)-N-methylpropane-1,3-diamine (1:1) **CAS:** 3,6-Dichloro-2-methoxybenzoic acid compound with N1-(3-aminopropyl)-N1-methyl-1,3-propanediamine (1:1) **CAS No.:** 1286239-22-2 **Formula:** $C_{15}H_{25}Cl_2N_3O_3$ **MW:** 366.28 g/mol **SMILES:** NCCCN(C)CCCN.ClC1=CC=C(Cl)C(C(O)=O)=C1OC		835.8100 Field volatility	51049002 51049003 51049004	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means “applied radioactivity”. MW means “molecular weight”. NA means “not applicable”.

Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Air sampling periods and soil temperature and moisture graphs

100094_51049002_DE
R-FATE_835.8100_5-5-

2. Validation spreadsheet for the Indirect Method

100094_51049002_DE
R-FATE_835.8100_4-28

3. Validation spreadsheet for the Integrated Horizontal Flux Method:

100094_51049002_DE
R-FATE_835.8100_4-28

4. Validation spreadsheet for the Aerodynamic Method:

100094_51049002_DE
R-FATE_835.8100_5-04

5. Air modeling files

100094 51049002 air modeling.zip

6. Validation spreadsheet for spray drift calculations

100094_51049002_DE
R-Fate_840.1200_8-29

7. Terrestrial Plants: Vegetative Vigor. MRID 51049002, EPA Guideline 850.4150

Folder: 100094 51049002 850.4150

Attachment 3: Field Volatility Study Design and Plot Map

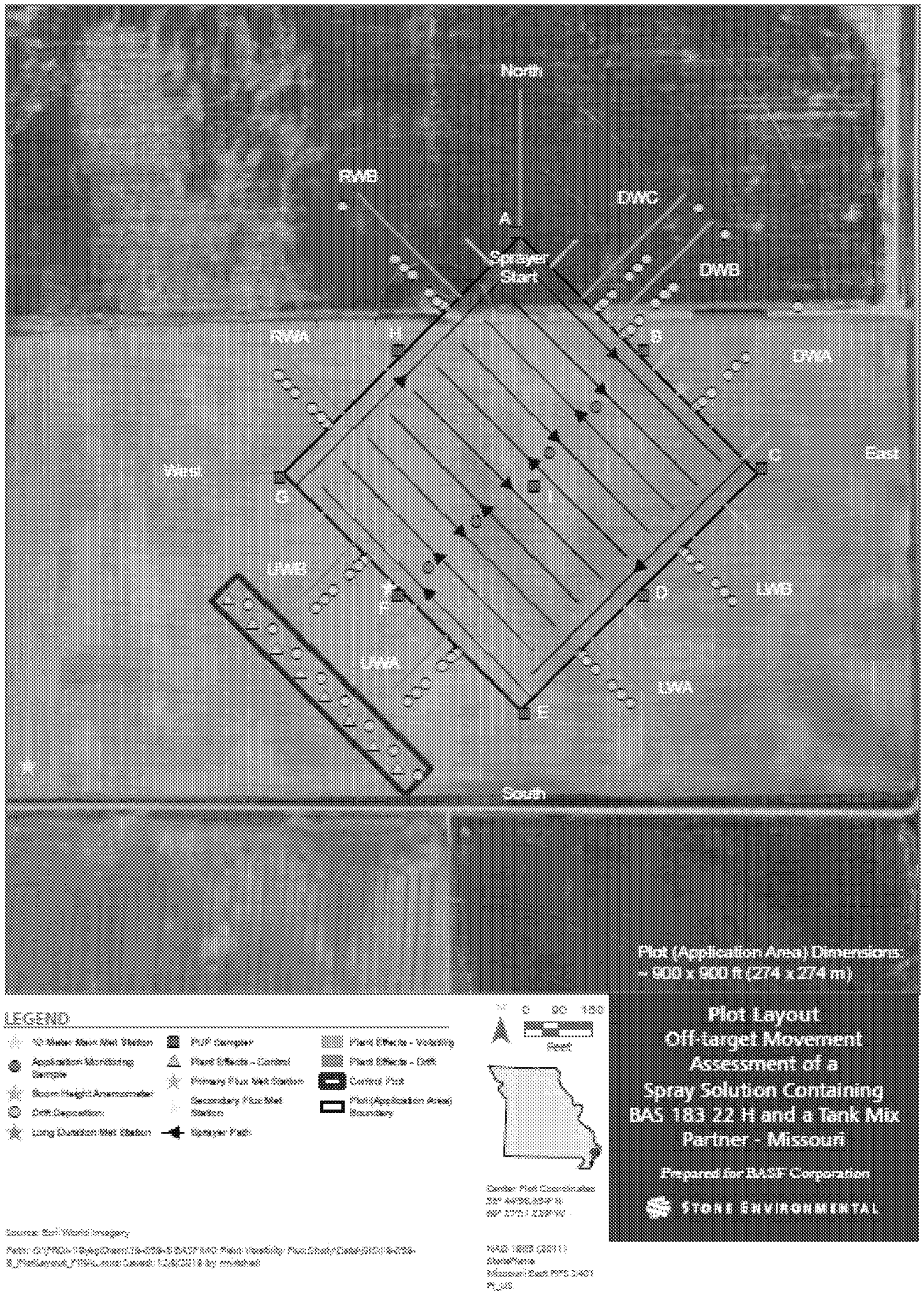


Figure obtained from Appendix B, Figure 5, p. 147 of the study report.

ED_005172C_00001462-00036